HAWAII PRECIPITATION FREQUENCY STUDY

Update of *Technical Paper No. 43*

Fourth Progress Report
1 January through 31 March 2002

Hydrometeorological Design Studies Center
Hydrology Laboratory

Office of Hydrologic Development
U.S. National Weather Service
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DISCLAIMER

The data and information presented in this report should be considered as preliminary and are provided only to demonstrate current progress on the various technical tasks associated with this project. Values presented herein are NOT intended for any other use beyond the scope of this progress report. Anyone using any data or information presented in this report for any purpose other than for what it was intended does so at their own risk.

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1. Introduction.

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development, U.S. National Weather Service is updating its precipitation frequency estimates for Hawaii. Current precipitation frequency estimates for Hawaii are contained in *Technical Paper No. 43,* "Rainfall-Frequency Atlas of the Hawaiian Islands for Areas to 200 Square Miles, Durations to 24 Hours, and Return Periods from 1 to 100 Years" (U.S. Weather Bureau 1962). The update includes collecting data and performing quality control, compiling and formatting datasets for analyses, selecting applicable frequency distributions and fitting techniques, analyzing data, mapping and preparing reports and other documentation.

The study will determine annual and seasonal precipitation frequencies for durations from 5 minutes to 60 days, for return periods from 2 to 1000 years. The study will review and process all available rainfall data for the Hawaii study area and use accepted statistical methods. The study results will be published as a Volume of NOAA Atlas 14. They will also be made available on the internet using web pages with the ability to download digital files.

The study area covers the Hawaiian islands including Hawaii, Maui, Lanai, Molokai, Oahu, and Kauai. The study area including preliminary regions is shown in Figure 1.

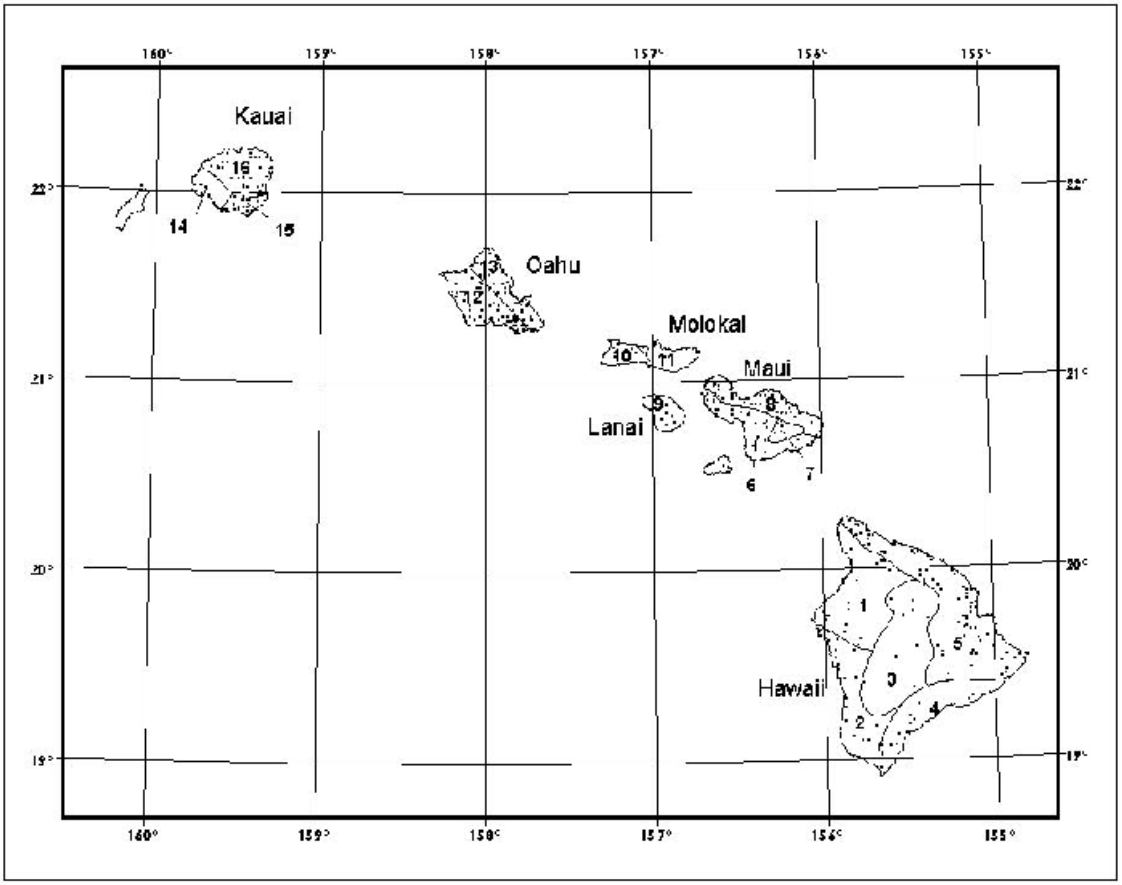

Figure 1. Hawaii Precipitation Frequency study area, regional divisions and daily station locations.

2. Highlights.

Data entry of monthly maximums from daily gages maintained by the State is underway by the University of Hawaii. Entry started with the Big Island in January. Additional information on this subject is available in Section 4.1.

Development is underway to add functionality to the Precipitation Frequency Data Server (PFDS) to extract station-specific data. This functionality will allow for a review of the point-precipitation frequency estimates before the interpolated grids are finalized. Additional information is provided in Section 3.1.3.

We have developed and tested software to extract annual maximums of long duration events (4-day through 60-day). Software has been developed to screen 1-day annual maximum series for large gaps in time using specified "Gap Check" criteria. Stations will be merged and adjustments made where appropriate to produce more congruent data records. Additional information is provided in Section 4.2**.**

3. Status.

3.1 Project Task List.

The following checklist shows the components of each task and an estimate of the percentage completed per task. Past status reports should also be referenced for additional information.

Hawaii study checklist [estimated percent complete]:

Data Collection, Formatting and Quality Control [25%]:

- Daily
- Hourly
- 15-minute
- N-minute

L-Moment Analysis/Frequency Distribution for 5 minute to 60 days and 2 to 1000 years [0%]:

- Daily
- Hourly
- 15-minute
- N-minute

Algorithm/Data Plot [10%]

- Establish regions from spatial, topographic and meteorological variables
- Run L-moments for regional growth factors to generate dataset
- Create grids of distributed means for each duration using PRISM (see Table 1)
- Subject grids of distributed means to external review
- Create smoothed regional growth factor (RGF) grids using GRASS: (5-1000) yr (1-12) hr, (5-1000) yr 24hr, (5-1000) yr (2-60) day

Table 1. Proposed List of Grids of Distributed Means.

Duration	**Season**
1-hr	all
1-hr	cool, warm
2-hr	all
3-hr	all
6-hr	all
6-hr	cool, warm
12-hr	all
24-hr	all
24-hr	cool, warm
48-hr	all
4-day	all
7-day	all
10-day	all
20-day	all
30-day	all
45-day	all
60-day	all
Total: 26 (14 all, 6 warm, 6 cool)	

Precipitation Frequency Maps [0%]

- Multiply appropriate RGF and grids of distributed means to produce precipitation frequency grids for durations and seasons shown in Tables 1 and 2
- Apply domain-wide conversion factor to the 1-hour precipitation frequency grids to calculate the n-minute (5-, 10-, 15-, and 30-minute) grids
- Perform internal consistency checks (comparing rasters of sequential duration and frequency)

Table 2. Proposed List of Precipitation Frequency Rasters.

Duration	**Frequency**	**Season**
5-min	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
5-min	2-yr, 100-yr	cool, warm
10-min	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
10-min	2-yr, 100-yr	cool, warm
15-min	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
15-min	2-yr, 100-yr	cool, warm
30-min	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
30-min	2-yr, 100-yr	cool, warm
1-hr	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
1-hr	2-yr, 100-yr	cool, warm
2-hr	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
3-hr	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
6-hr	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
6-hr	2-yr, 100-yr	cool, warm
12-hr	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
24-hr	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
24-hr	2-yr, 100-yr	cool, warm
48-hr	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
4-day	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
7-day	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
10-day	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
20-day	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
30-day	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
45-day	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
60-day	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all

Data Trend Analysis [0%]

- Analyze linear trends in annual maxima and variance over time
- Analyze shift in means of annual maxima between two time periods (i.e., test the equality of 2 population distribution means)

Seasonal Analysis [0%]

- Create graphs of percentage of precipitation maxima in each month of a year

Temporal Distributions of Extreme Rainfall [0%]

- assemble hourly data by quartile of greatest precipitation amount and convert to cumulative rainfall amounts for each region
- prepare graphs of representative storm-types and seasons

Deliverables [20%]

- Prepare data for web delivery
- Prepare documentation for web delivery
- Write hard copy of Final Report
- Publish hard copy of Final Report

Additional Work:

Spatial Relations (Depth Area Duration Study) [20%]

- Obtain data from dense-area reporting networks
- QC and format data from dense networks
- Compute maximum and average annual areal depth for each duration from stations from each network
- Compute ratio of maximum to average depth for all durations and networks and plot
- Draw curves of best fit (depth area curves) for each duration and network

3.1.1 Data Collection and Quality Control.

The University of Hawaii will continue digitizing daily data from a network of state operated gauges. Once this data is added to our data set the number of daily stations will greatly increase. The University will enter monthly maximums of daily data. Data from the Big Island will be entered first and subsequently provided to the HDSC to begin final QC and processing. Data entry by the University will then concurrently continue westward up the island chain as the HDSC processes data from the Big Island.

3.1.2 Spatial Interpolation.

Contract formalities between HDSC and the Spatial Climate Analysis Service (SCAS) at Oregon State University (OSU) have been finalized. Tasks under this contract will serve as a prototype for the approach to be used in the Hawaii study. PRISM (Parameter-elevation Regressions on Independent Slopes Model) will be used by SCAS to spatially interpolate the mean annual maxima values (a.k.a. “index flood”) to grids. At HDSC, the “index flood” grids will be multiplied by the appropriate regional growth factor (RGF) grid to derive each of the precipitation frequency grids. We are evaluating different spatial smoothing techniques to mitigate any potentially large RGF boundary differences.

3.1.3 Precipitation Frequency Data Server.

The Hawaii study results will be available on the HDSC Precipitation Frequency Data Server once mapping is complete and reviewed. The Data Server displays precipitation frequency values and intensity-duration-frequency curves and tables.

Development is underway to add functionality to the Precipitation Frequency Data Server (PFDS) to extract station-specific data. Until now, users could only select a longitude/latitude location or an area, but soon the PFDS will have a pull-down menu to select a specific climate station. The menu of climate stations will represent the same stations used in the study, including the option of choosing which type of gage data (N-minute, hourly, or daily) to extract. Likewise, the data will be the exact data as output by the L-moment software used in the study. This functionality will allow for a review of the point-precipitation frequency estimates before the interpolated grids are finalized.

3.1.4 Spatial Relations (Depth Area Duration Study)

Depth Area Duration (DAD) reductions for areas from 10 to 400 square miles are being updated for the entire United States and will be presented in a report separate

from NOAA Atlas 14. (Additional information is provided in previous progress reports and Section 4.3)

4. Progress in this Reporting Period.

4.1 Data Collection and Quality Control.

A complete listing of State rainfall records for Hawaii County (The Big Island) has been completed by the University of Hawaii. For each station, the state key number, latitude, longitude, elevation, observer's name, and record length has been compiled. Out of a total of 400+ state stations, 136 have data of 20 years or longer. These stations contain data from 1955 onward. There are additional stations discovered on the Big Island with data dated from 1948. There were two extreme rain events noted with more than 10 inches of rainfall within 24 hours which occurred during the 1948-54 period. Because there were interesting storm events between 1948 and 1955 and adding these seven years would yield more gages with more than 20 years of data, the consensus is that the data base should be extended back to 1948. Additional information on this subject is contained in Section 5.2.

A second student has been hired by the University of Hawaii to help digitize data.

HDSC received the daily data set, TD3206 from the National Climate Data Center (NCDC) for the Hawaiian Islands. This digital data set contains data from before 1949. We will update our database with TD3206 and NCDC data thru 2001 when hand entry of the state data has been completed by the University of Hawaii.

4.2 Software Updates.

Some stations included in the Study may have multiple missing years. Large gaps (i.e., sequential missing years) in an annual maximum series (AMS) cause concern over the data series consistency. It is not possible to guarantee that two given data segments are from the same population (same climatology, same rain gauge, and same exact physical environment) from one side of the gap to the other.

Therefore, software has been developed to screen all data records for these large gaps using specified "Gap Check" criteria before the data will be used in the L-moment analysis. Station records with large gaps are flagged by the software and examined on a case by case basis using a conservative approach. Nearby stations will be inspected for concurrent data years to fill in the gap if they pass the statistical test for consistency. Latitude, longitude and elevation were taken into account when examining nearby stations. Also, if there are sufficient numbers of years in each data segment, a t-test will be conducted on the two segments to assess the statistical integrity of the data record.

Software to extract annual maximums of longer duration events based on the annual maximum criteria has been developed and tested. Therefore, we now have the tools to extract the annual maximum series for 1-day through 60-day precipitation accumulations once the datasets are finalized.

4.3 Spatial Relations (Depth Area Duration Study)

Depth Area Duration (DAD) reductions for areas from 10 to 400 square miles are being updated for the entire United States and will be presented in a report separate from NOAA Atlas 14. This quarter the focus has been on gathering and formatting data from geographically spaced dense area rain gage networks (DRNs) across the United States. These DRNs will be used in conjunction with NCDC hourly stations to develop DAD relationships. Thirteen networks have been identified thus far and are summarized in the table below.

Table 3. Dense Area Rain Gage Networks (DRN's).

DRN	Period of Record (Concurrent)	Number of Stations
Coshocton, OH	1940 - 1990	10
Riesel, TX	1968 - 2001	21
Walnut Gulch, AZ	1955 - 1990	18
Reynolds Creek, ID	1965 - 1996	52
Tifton, GA	1968 - 1980	45
Alamogordo Creek, NM	1955-1977	66
Hastings, NE	1939-1962	10
Safford, AZ	1939-1971	11
Hawaii (NCDC data)	1965-2000	32
Danville, VT	1960-1974	13
Blacksburg, VA	1957-1972	15
Goodwin, MI	1981-2001	67
Lafayette, IN	1940-1953	8

5. Issues.

5.1 Updating Precipitation Frequency Atlases for the Entire Nation.

HDSC is currently updating the precipitation frequency atlases for a number of areas across the country and has been asked to expand the work to the entire country. Studies are concurrently underway for the Ohio River Basin and surrounding states, the Semiarid Southwest, Hawaii, and Puerto Rico and the Virgin Islands. Quarterly progress reports, which include schedules, for these studies are available at http://www.nws.noaa.gov/oh/hdsc.

Precipitation frequency studies are performed using funds provided by other federal, state and local agencies. HDSC is participating in an effort to assemble funds to update the precipitation frequency atlases for the entire United States. Hopefully sufficient funds can be identified to begin work during the summer of 2002. The full national update will use a consistent technical approach to data preparation, frequency analysis and mapping and as well as a consistent and more user-oriented approach to publication.

5.2 Hand Entry of State Gage Data.

Schedules for the hand entry of State daily data by the University of Hawaii were previously calculated to include only data from 1955 through the present. Because there were interesting storm events between 1948 and 1955 and adding these seven years would yield more gages with more than 20 years of data, the consensus is that the data base should be extended back to 1948. However, it is also recognized that compilation and digitizing the extended dataset is a time consuming task and extra time (about 4 months) and supplementary budget ($10,000) would be needed. Sources for additional budget may include the City and County of Honolulu, Kauai County, Department of Transportation, Department of Defense, and Kamehameha Trust. A revised budget and timeline will be distributed by the University during the next quarter. Meetings to discuss these issues are scheduled on a monthly basis at the University.

6. Projected Schedule.

The following list provides a tentative schedule with completion dates. Brief descriptions of tasks being worked on next quarter are also included in this section. The University of Hawaii Digitizing completion date is indicated as Month Zero (M_0).

Data Collection and Quality Control [M_0 + 3 months]
L-Moment Analysis/Frequency Distribution [M_0 + 5 months]
Seasonal Analysis [M_0 + 5 months]
Temporal Distributions of Extreme Rainfall [M_0 + 8 months]
Implement review by peers [M_0 + 8 months]
Trend Analysis [M_0 + 9 months]
Spatial Interpolation [M_0 + 10 months]
Precipitation Frequency Maps [M_0 + 11 months]
Write hard copy of Final Report [M_0 + 12 months]
Publish hard copy of Final Report [M_0 + 14 months]
Spatial Relations (Depth Area Duration Studies) [January 2003]

6.1 Data Collection and Quality Control.

An agreement has been established between the HDSC and the other funding agencies to wait for the University of Hawaii to manually digitize daily rainfall data from a network of state maintained rain gauges. The current estimation from the University is the data entry should be completed by the end of January 2003. This will cause a delay of the same length to the project while the HDSC waits for the data. The Big Island will be digitized first and should be completed by the end of the Spring 2002 semester. The entry of the remaining islands will immediately follow. These delays are reflected in the projected schedules. During the next quarter the University will continue to hand enter data for the Big Island and probably begin hand entry for Maui County. The projected schedule is summarized in Table 4.

Table 4. Projected Schedule of Hand Entry of State Daily Gage Monthly Maximums.

Island	**Projected Completion Date**
Big Island	4/25/02
Maui County (Maui, Lanai, Molokai)	7/26/02
Oahu	10/25/02
Kauai	1/25/03

6.2 Precipitation Frequency Maps.

Two Precipitation Frequency Data Server changes planned for the next quarter are extending the return period to 1000 years and changing the precipitation frequency estimate graph from a bar to a line graph.

6.3 Spatial Relations (Depth Area Duration Study)

Research will continue into selecting the method to be used for computing the DAD curves. Software to decode and format the data files and the DAD computations will continue to be developed. As DRN's are located, they will be added to our database.

6.4 Temporal Distributions of Extreme Rainfall.

Research will continue in confirming our methodology for developing temporal distributions of extreme rainfall events. Our method is based on an Illinois State Water Survey Report (Huff, 1990) and determines the maximum and median precipitation event time distributions for 12, 24 and 72 hour duration events. Time distributions of hourly maximum and median events will be sorted, averaged and plotted by storm area, quartile, duration and season.

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